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DTU Mechanical Engineering
Department of Mechanical Engineering

Active Magnetic Regenerative Refrigeration

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The concecpt of magnetic refrigeration

is based on the magnetocaloric effect (MCE) seen in ferro-magnetic materials.

When a magnetic material is exposed to a change in external magnetic field adiabatically the temperature of the material changes. If the field change is positive the temperature increases and vice versa.

The MCE typically has a maximum of a few K pr tesla of the changed field. Therefore regeneration has to be used to obtain greater temperature spans. The so-called Active Magnetic Regeneration (AMR) cycle is used. This is explained in Fig. 1. The AMR cycle is compared to conventional vapor compression-based refrigeration in Fig. 2.

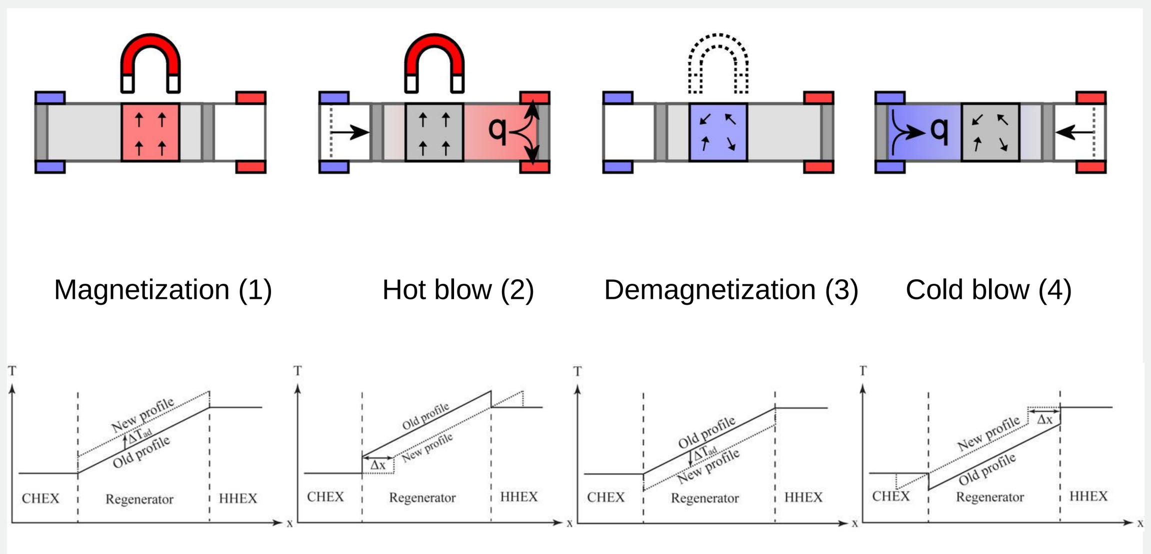

Fig. 1 The four steps of the Active Magnetic Regeneration (AMR) cycle described with the steady-state temperature profile envisioned. First the regenerator made of a solid magnetocaloric material is magnetized by an external magnet (1) and the temperature increases. Then the heat transfer fluid (e.g. water) is moved from the cold to the hot end to reject heat to the ambient (2). This is the so-called "hot blow". The third (3) step is demagnetization where the solid is cooled below its initial temperature. Finally, the fluid is moved from the hot to the cold end (4) and a heat load can be absorbed from e.g. the inside of the refrigerator.

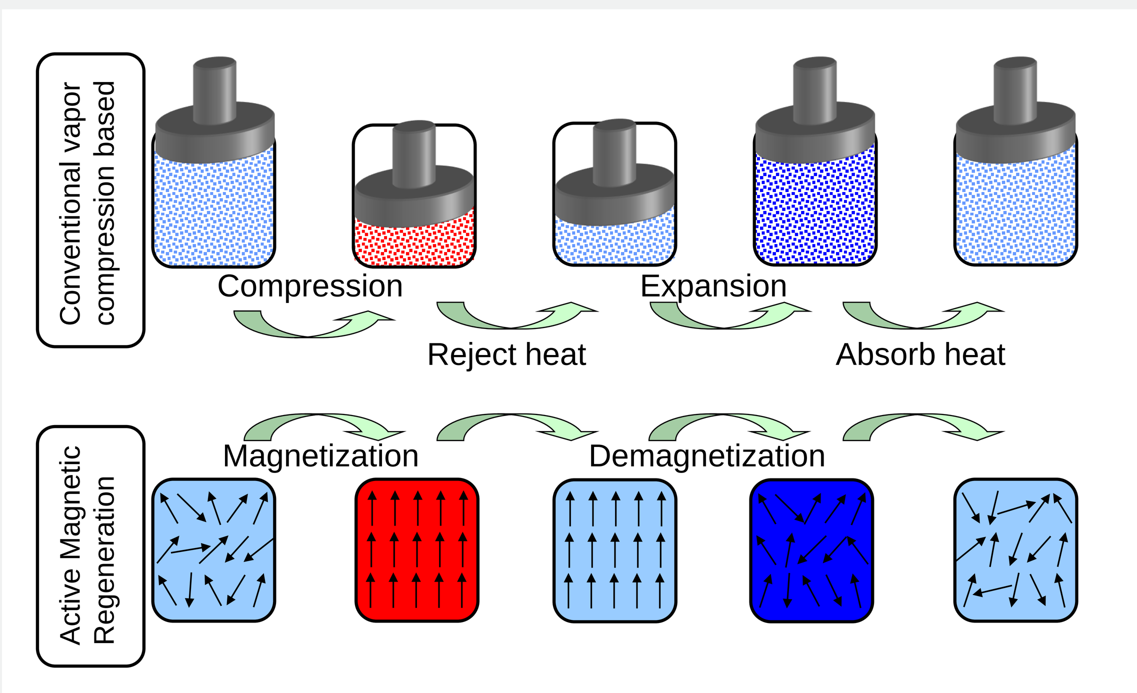

Fig. 2 The Active Magnetic Regeneration (AMR) cycle visualized and compared to conventional vapor compression based refrigeration.

Introduction: Magnetic refrigeration at room temperature is a potential environmentally friendly and energy efficient technology for a variety of applications such as domestic refrigeration, air conditioning etc.

Challenges

The challenges can be divided into three parts.

- ❑First of all a large magnetic field change is desirable since the MCE scales with the field change. Electromagnets may not be practical for most magnetic refrigeration applications, and therefore high field permanent magnets must be developed
- ❑Second, the regenerator efficiency should be as high as possible while keeping the total pressure drop relatively low
- ❑Third, the MCE is quite small and is a strong function of temperature. Therefore multi-material, or composite, regenerators are needed.

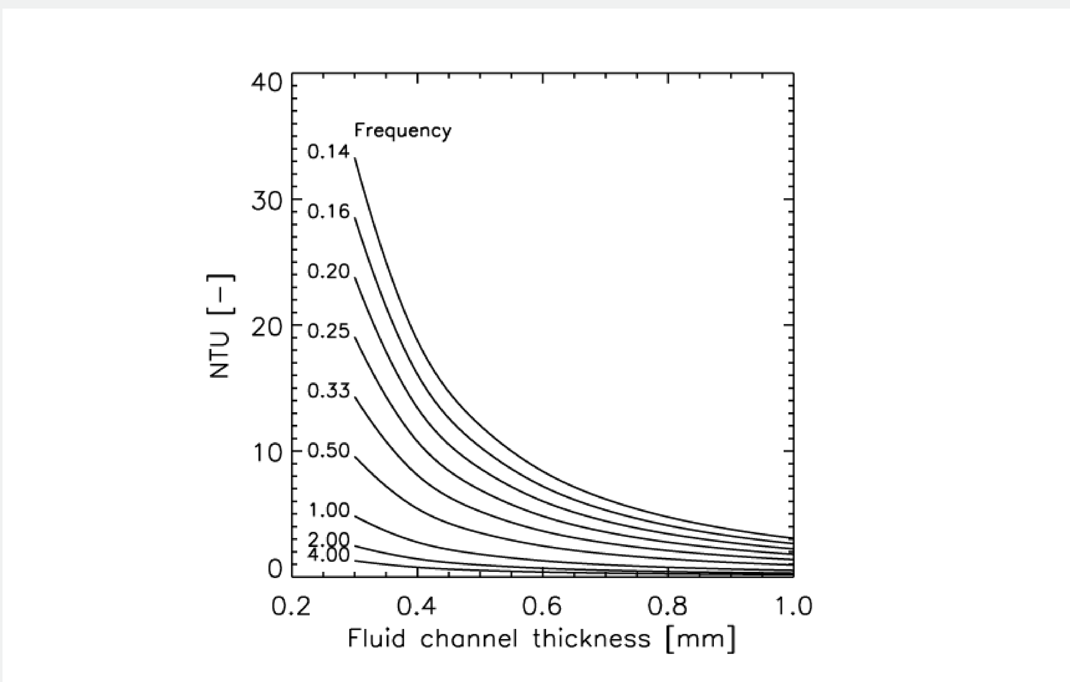

Fig. 3 The Number of Transfer units (NTU) for laminar low between parallel plates as function of the spacing, or channel thickness, and the operating frequency.

Several geometries are suggested. The most common are:

- ❑Packed spheres, which have (too) high pressure drop and very high heat transfer
- ❑Parallel plates, which have very low pressure drop but perhaps also too low heat transfer

Fig. 3 shows the NTU of laminar flow between parallel plates as function of spacing and operating frequency. The NTU should be in the range 10-30 for optimal performance (less is too little, more is over-kill), see Nielsen et al. (2009b) for more info.

Fig. 4 shows samples of different geometries currently available at Risø DTU. These include stacked parallel (possibly dimpled) plates and extruded monolithic structures.

In Fig. 5 the concept of multi-material regenerators is described and supported using a detailed model.

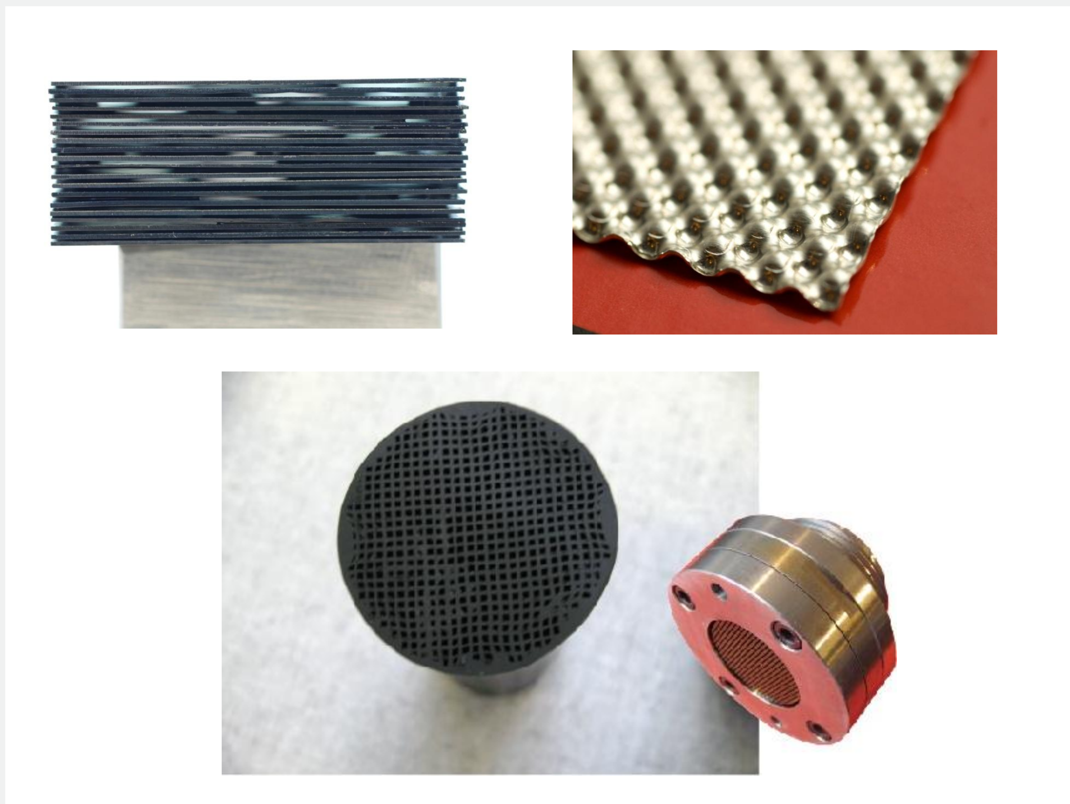

Fig. 4 Three examples of regenerator geometries. Upper left is a stack of plates of the material $La_{0.67}Ca_{0.26}Sr_{0.07}MnO_3$. The plates are 0.3 mm thick and spaced with 0.2 mm. Upper right shows and examples of a dimpled plate. The idea is to stack plates so that every second is dimpled and every other is flat. Lower middle shows an extruded monolithic structure of the same material as the plates. Here the flow channel cross sections are (0.8mm)^2 and the walls 0.4 mm thick.

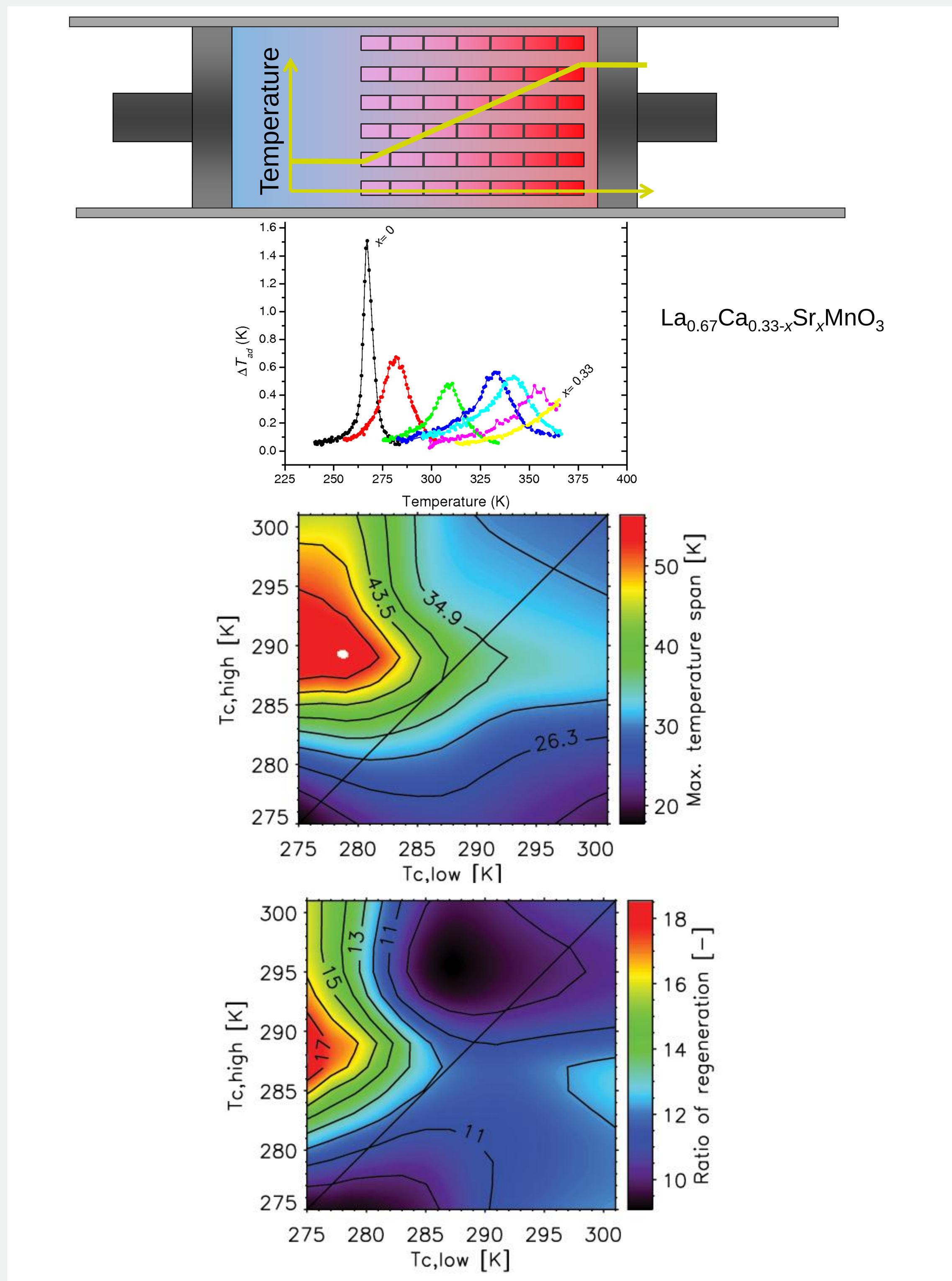

Fig. 5 The figure shows a few examples of how composite materials may enhanced the AMR system. The upper figure shows the concept of a graded regenerator and an example of an MCM where the Curie (or peak) temperature can be tuned. The two lower figures show results from numerical simulations where the AMR has been composed of two fictitious materials with different Curie temperatures. Both the maximum temperature span is enhanced as well as the ratio of regeneration defined as the temperature span divided by the mean adiabatic temperature change in the system.

References

Nielsen, K.K., Bahl, C.R.H, Smith, A., Bjørk, R., Pryds, N. and Hattel, J., "Detailed numerical modeling of a linear parallel-plate Active Magnetic Regenerator, Int. J. of Refrigeration, 2009a.

Nielsen, K.K, Bahl, C.R.H, Smith, A., Pryds, N., Hattel, J., "On the ideal cooling capacity of gadolinium in Active Magnetic Regenerative Refrigeration", submitted, 2009b.

Bahl, C.R.H, Petersen, T.F., Pryds, N. and Smith, A, "A versatile magnetic refrigeration test device", Rev. of Scientific Instruments, 2008.

Engelbrecht, K., Jensen, J.B., Bahl, C.R.H and Pryds, N., "Experiments on a modular magnetic refrigeration device", in proceedings, 3rd International Conference on Magnetic refrigeration at room temperature", 2009.

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